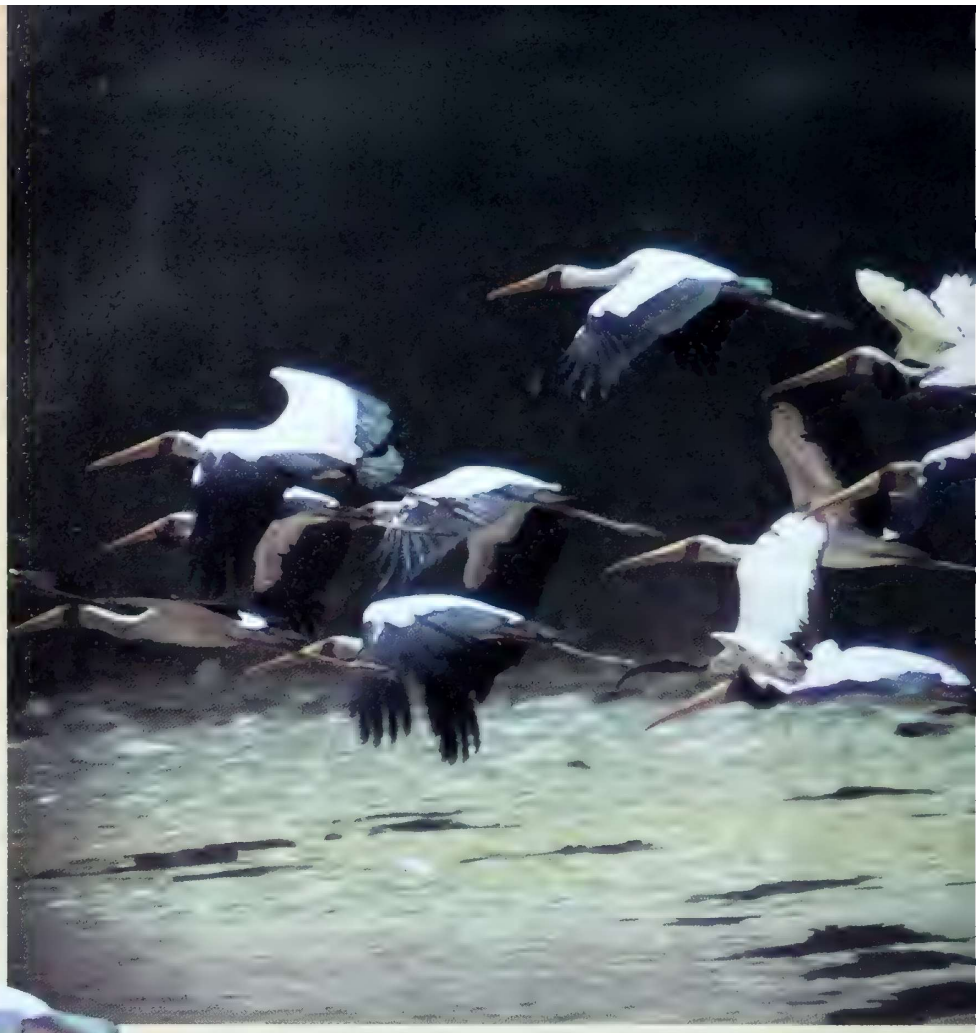
CHAPTER 1

The Nature of Science





Storks flying south to their winter home in Kenya

Toward the end of August, you may have taken a walk through your neighborhood. That neighborhood may be one of buildings and pavement, lawns and trees, fields and pasture, or even sand and cactus. Such walks often inspire questions. Why do days get shorter at this time of year? Why does grass stop growing in the fall? Why do some plants flower in spring and others in autumn? How do geese know when to fly south for the winter? How do they even know which way is south?

Like yourself, scientists ask themselves similar questions about their world. Sometimes they find answers—as you do. Sometimes the answer remains to be discovered. And sometimes there is no answer. The important point is not finding the answer but asking the question. For making observations and asking questions is at the very heart of the process known as science.

CHAPTER OUTLINE

1–1 What Is Science?

1–2 The Scientific Method
- Observing and Stating a Problem
- Forming a Hypothesis
- Testing the Hypothesis
- Recording and Analyzing Data
- Forming a Conclusion
- Replicating the Work
- Hypotheses and Theories
- The Scientific Method—An Everyday Experience
- A Universal Language—The Metric System

1–3 Science: "Facts" and "Truth"
- How to Study Science
- Science and Human Values

1–4 Safety in the Laboratory

1–5 The Spaceship Called Earth

1–1 What Is Science?

Section Objective

- Identify the main goal of science.

Asking questions about the world around us is part of human nature. How did life begin? Where did plants and animals come from? Why do animals behave as they do? Every culture in the world has tried to answer these questions—often through myths and legends.

The Pitjendara tribe of central Australia, for example, finds answers to questions about nature on an enormous mound of stone called Ayer's Rock. The rock, which towers more than 300 meters above the flat desert around it, has been carved by centuries of exposure to wind and rain. Erosion has etched gullies and caverns into the rock, and has produced striking formations on its surface. See Figure 1–1.

According to the Pitjendara, the images etched on Ayer's Rock tell stories that depict the adventures, the loves, and the battles of ten enormous creatures. The rock contains the likenesses of two snakes, Liru and Kunia. The Pitjendara believe that the two snakes fought an epic battle that created many features on the southern face of Ayer's Rock. Elsewhere on the rock, a sand-lizard man left his mark digging for water. Through these and other stories, the Pitjendara explain the formation of the world and the processes of birth, life, and death.

The stories of the rock also detail the connections between the tribe and animals important in their everyday lives: snakes,



Figure 1–1 *To the Pitjendara, these etchings on Ayer's Rock represent the human brain.*



Figure 1–2 *Ayer's Rock in central Australia is the largest individual rock in the world. Why might people who live their entire lives in this area develop myths and legends about Ayer's Rock?*

desert lizards, and kangaroos. The stories even explain the origins of dreams. We might say that the rock provides the Pitjendara with answers that other societies seek through a process known as science.

People like the Pitjendara live their entire lives in a single culture. Thus, they often find it difficult to imagine that their particular stories about the world might be in error. Today, however, we can visit and read about many cultures. And when we assemble stories from around the globe, it becomes obvious that all these stories cannot be true.

Is there some other way to explain the world around us? One way is to assume that all events in nature have natural causes. We can then try to arrange a series of observations or tests to learn what those causes are. **Science** is the word that we apply to this process. **The goal of science is to understand the world around us**. There are, however, many important fields of human endeavor that study the world around us but are not considered sciences. Such fields include language, history, art, music, and philosophy. The character that distinguishes science from nonscience is an approach known as the scientific method.

Figure 1–3 *These stone statues were created by people living on Easter Island in the Pacific Ocean. The statues may well represent the Easter Islanders' belief that the first humans hatched from eggs brought to Earth by a bird-man.*



1-1 SECTION REVIEW

1. What is the goal of science?
2. Compare the study of science with the study of literature. How do they differ? How are they similar?

1–2 The Scientific Method

Section Objectives

- Describe the steps in the scientific method.
- Compare a control setup and an experimental setup.
- Identify the basic units of length, mass, volume, and temperature in the metric system.

The simplest definition of the **scientific method** was offered by biologist Claude Villee. He called it "Organized common sense." That is exactly what science should be. **In practice, the scientific method consists of several steps:**

- **Observing and stating a problem**
- **Forming a hypothesis**
- **Testing the hypothesis**
- **Recording and analyzing data**
- **Forming a conclusion**
- **Replicating the work**

To the true scientist, however, the scientific method is more a frame of mind—a frame of mind that involves curiosity. For without curiosity about nature, there would be no interest in why the sun appears to rise and set, why the seasons change, or why a snake sheds its skin. Another important characteristic of the scientific spirit is the refusal to accept an explanation without evidence or proof. This "prove it!" attitude encourages scientists to investigate phenomena and to develop new explanations and ideas.

Observing and Stating a Problem

The process of science starts with an observation. For example, we might notice that the leaves of maple trees turn bright red and yellow in autumn. As curious scientists, we would then be interested in discovering why this color change takes place.



Figure 1–4 *The changing colors of the leaves in Vermont is an event to which people travel from all over the country to enjoy. What hypothesis could you suggest to explain why the leaves of many trees change color in autumn?*

Forming a Hypothesis

We proceed to gather information that helps us generate a **hypothesis**. A hypothesis is a possible explanation, a preliminary conclusion, or even a guess about some event in nature. For example, we can observe that maple leaves change color when the air gets colder. We might then hypothesize that color changes in maples are related to changes in temperature.

Testing the Hypothesis

Next we must test our hypothesis. Some hypotheses may be tested simply through further observation. As you will discover in Chapter 13, Charles Darwin spent most of his life in the field observing nature to test his hypotheses about evolution. Most hypotheses, however, must be tested by experiments. The "autumn leaves" hypothesis falls into this category.

Our observations indicate that leaves change color in the autumn. And our hypothesis is that the color change is related to changes in temperature. We must now perform a test to find out if this is a correct explanation. One experiment we might do is to take a small maple tree growing in a pot and place it in a growth chamber during the month of July. We would lower the temperature to typical autumn levels, about 14°C during the daytime and 3°C at night. If our hypothesis is correct, we might see the leaves begin to change color almost immediately.

Suppose we ran this experiment and the leaves did change color. Would we know for certain that changes in temperature alone were responsible for the color change? After all, there are many differences between the tree in our experiment and a tree in the woods. Did the leaves on our tree turn red because the tree was planted in a small pot? Or because the light inside the growth chamber was different from natural light?

These uncertainties point out the need for a more complicated experiment using at least two trees. We should choose two similar trees and pots of the same size, water the trees at the same time, and place them in identical chambers. We should then conduct an experiment in which one chamber is kept at normal summer temperatures while the other chamber is cooled to autumn temperatures.

Why must we go to the trouble of observing a second tree? This two-part test represents what is called a controlled experiment. Controlled experiments allow researchers to isolate and test the effects of a single factor, or experimental **variable**. In this case, the treatment of the first tree serves as our **control setup** by testing the effects of the pot and growth chamber. The treatment of the second tree, our **experimental setup**, is identical to the control setup in every respect except one—the variable of temperature. See Figure 1–5. Now if we observe a difference between the experimental setup and the control setup, we can be more certain that it is due to the lower temperatures in the experimental chamber.



Figure 1–5 *Whenever possible, an experiment should have both a control setup and an experimental setup. Which part of the experiment contains the variable? What is the variable in this experiment?*

Recording and Analyzing Data

If we were actually to perform this experiment, we would keep careful records of observations and information, or **data**. In this case, such data might include the time it took for each leaf to change color, the total number of leaves on each tree that changed color or fell off, and so on. We might arrange our data in the form of tables and graphs, such as those shown in Figure 1–6. You can see why researchers use these visual representations of experimental data to analyze their results.

EXPERIMENTAL SETUP: Autumn Temperatures

Day	1	3	5	7	9	11	13	15	17	19	21
Number of Green Leaves	50	50	50	49	49	48	48	48	48	47	47

CONTROL SETUP: Spring Temperatures

Day	1	3	5	7	9	11	13	15	17	19	21
Number of Green Leaves	50	50	49	49	49	49	49	47	47	47	47



Figure 1–6 *Information gathered from an experiment is usually organized in data tables (top). Then the data may be graphed in order to provide a visual representation that is easy to interpret (bottom). Using the data tables and the graph, what conclusions can you reach about the autumn leaves hypothesis?*

Forming a Conclusion

If we find that the leaves on our experimental tree change color and those on the control tree do not, we may decide that we have confirmed our original hypothesis: Cold temperatures cause leaves to change color. If the leaves of neither tree change color or if the leaves of both trees change color, we might reject the hypothesis as wrong and start all over with a

new idea. This is often the case in science because many guesses about the natural world prove incorrect. But this is also the way science advances, for it points the way to further experiments. If the leaves on neither tree change color, for example, it is possible that temperature alone is not responsible. Perhaps trees also respond to changes in the length of day, decreases in rainfall, or the action of strong winds. These new hypotheses suggest additional experiments that expand our understanding.

Although such experiments are probably impossible for you to perform yourself, scientists have been able to do them and have arrived at an answer to our original hypothesis: Do the colder temperatures of autumn cause a color change in the leaves of maple trees? If you have examined the data in Figure 1–6, you know part of their conclusion: Colder temperatures alone do not cause the color change. Scientists now know that colder temperatures combined with a change in the length of day both play a role in the color change in maple leaves. In addition, many scientists believe that a biological clock within the maple tree also plays a role. But how does this biological clock work? And what chemical triggers the clock? These are questions that as yet remain unanswered. If you should choose to pursue biology as a career, perhaps you will consider these questions once again.

Replicating the Work

The best scientific experiments can be replicated, or reproduced. In other words, it must be possible for either the original experimenter or other researchers to duplicate, or reproduce, the experimental results. Reproducibility in science takes many forms. We might want to replicate the experiment ourselves several times. Or we might want to put several trees in each growth chamber. Such actions would assure us that our results were not due to chance.

Another form of reproducibility is the replication of work by others. If interesting results come from an experiment, a researcher will publish a report of the work in a scientific journal. The report must contain enough detail so that other scientists can copy the experiment precisely to see if the same results continue to occur.

Hypotheses and Theories

When a hypothesis is tested and confirmed often enough that it is unlikely to be disproved by future tests, it may become worthy of being called a **theory**. In scientific usage, the word theory means a great deal more than it does in common speech. Scientific theories are not just hunches or hypotheses. They are powerful, time-tested concepts that make useful and dependable predictions about the natural world.

The Scientific Method—An Everyday Experience

Because many experiments discussed in this book were performed by people called scientists, you might think that science is a special process used only by certain people and useful only under special circumstances. That is not true at all. We all use the scientific method every day!

Let's suppose, for example, that a car will not start. A mechanic will form and test hypotheses about the problem. Perhaps the battery is dead. One experiment would be to crank the starter to see what happens. If the starter motor works but the car still doesn't turn over, it could be that the car is out of gas. A glance at the fuel gauge would test that idea. Again and again, the mechanic would apply the scientific method until the problem is solved. The same technique can find a fault in an electrical circuit or balance a load of laundry in a washing machine. Remember, science is just organized common sense.

A Universal Language—The Metric System

Science works best when scientists everywhere read each other's papers, check each other's experiments, and argue about what those experiments mean. Because most experiments involve measurements, researchers need a universal system of measurement in which to present their findings. **Scientists use the metric system of length, volume, mass, and temperature when describing experiments and data.** The **metric system** is a decimal system based on certain standards and scaled on multiples of 10. The metric system is also known as the International System of Units, or SI.

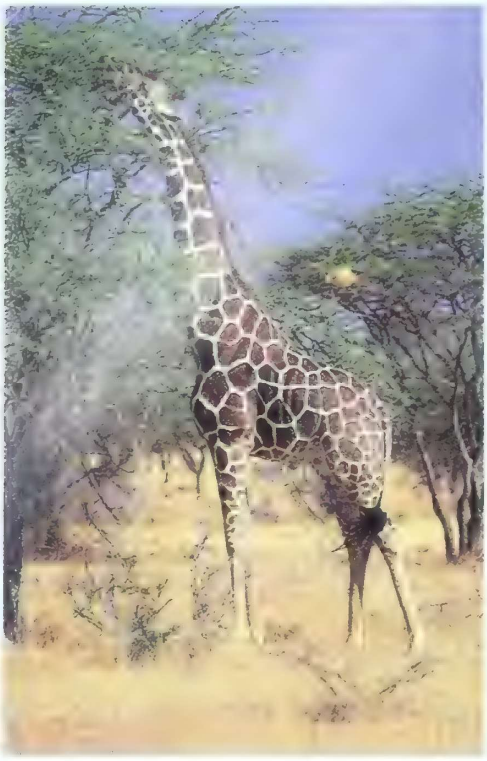
Figure 1–7 *The metric system is easy to use because it is based on units of ten. How many centimeters are there in 100 meters?*

COMMON METRIC UNITS

Length	Mass
1 meter (m) = 100 centimeters (cm)	1 kilogram (kg) = 1000 grams (g)
1 meter = 1000 millimeters (mm)	1 gram = 1000 milligrams (mg)
1 meter = 1,000,000 micrometers (μm)	1000 kilograms = 1 metric ton(t)
1 meter = 1,000,000,000 nanometers (nm)	
1 meter = 10,000,000,000 angstroms (Å)	
1000 meters = 1 kilometer (km)	

Volume	Temperature
1 liter (L) = 1000 milliliters (mL) or 1000 cubic centimeters (cm^3)	0°C = freezing point of water 100°C = boiling point of water

kilo- = one thousand	micro- = one millionth
centi- = one hundredth	nano- = one billionth
milli- = one thousandth	



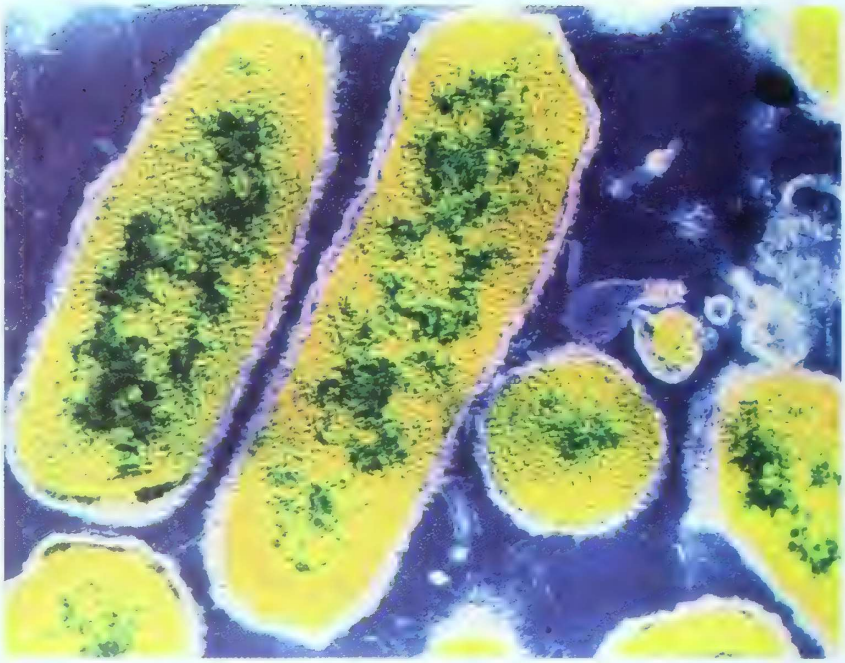


Figure 1–8 *Which unit of length would you use to measure this tall African giraffe (left)? This microscopic bacterium (right)?*

LENGTH The basic unit of length in the metric system is the **meter** (m). One meter is roughly equivalent to 39.4 inches, a little longer than a yard. To measure objects and distances much larger or smaller than a meter, the metric system uses units larger or smaller than a meter by multiples of 10. A centimeter (cm) is 1/100 of a meter—about the width of the nail on your pinky. As you may have guessed, the prefix *centi-* means one hundredth. A millimeter (mm) is 1/1000 of a meter. The prefix *milli-* means one thousandth. Even smaller units of length—such as those used to describe living cells, pieces of cells, and molecules—are shown in Figure 1–7 on page 11. To measure distances much greater than a meter, scientists use a unit called the kilometer (km). One kilometer contains 1000 meters. What does the prefix *kilo-* mean?

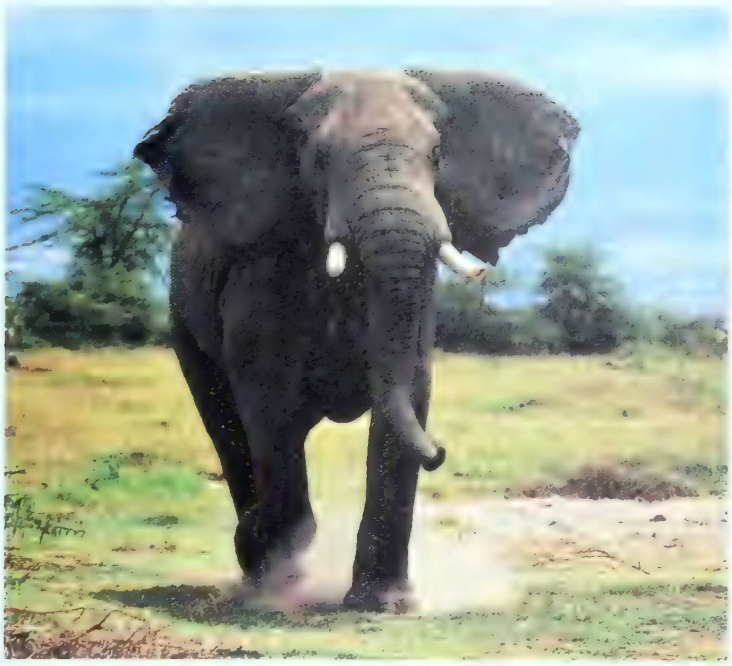
Figure 1–9 *Solids are usually measured in cubic centimeters. One cubic centimeter is the volume of a cube measuring one centimeter on each side. Keep in mind the illustration is not drawn to scale.*



Cubic Centimeter (cc or cm^3)

VOLUME Volume is the amount of space an object occupies. The basic metric units of volume are the **liter** (L) for liquids and the **cubic centimeter** (cc, or cm^3) for solids. A liter contains slightly more liquid than a quart. To measure small volumes of liquids, scientists use fractions of a liter called milliliters (mL). There are 1000 milliliters in a single liter. A cubic centimeter is the volume of a solid that measures 1 cm by 1 cm by 1 cm. Keep in mind that 1 milliliter is equal in volume to 1 cubic centimeter, or 1 mL = 1 cc.

MASS AND WEIGHT **Mass** is a measure of the amount of matter in an object. **Weight** is a measure of the pull of gravity on that mass. In outer space, the weight of an object may vary with its position, but its mass always remains the same. On Earth's surface, however, an object's mass and weight can



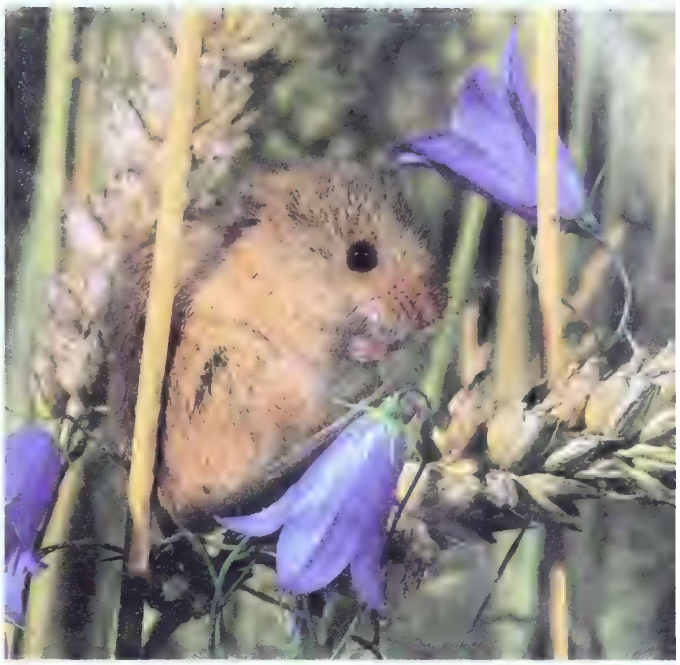
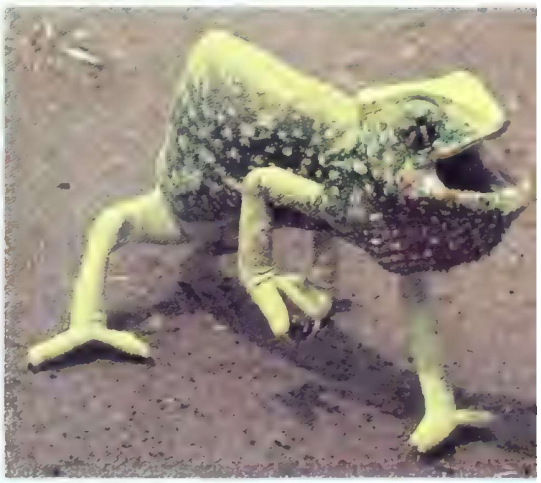


Figure 1–10 *The African elephant is among the largest land creatures ever to walk the Earth (left). The harvest field mouse is one of the smallest mammals on Earth (right). What unit would you use to measure the mass of the elephant? The harvest mouse?*

usually be considered constant and are often used interchangeably. The basic metric unit scientists use to describe mass is the **kilogram** (kg). One kilogram is equal to approximately 2.2 pounds. The mass of small objects is measured in grams (g). One gram is 1/1000 of a kilogram. How many milligrams (mg) are there in a gram? In a kilogram?

TEMPERATURE The metric system measures temperature using the **Celsius** (SEHL-see-uhs) **scale** (°C). On this scale, water freezes at 0°C and boils at 100°C. Each Celsius degree, therefore, represents exactly 1/100 of the temperature range between the freezing and boiling points of water. Normal human body temperature is about 37°C, and comfortable room temperature is about 21°C.

Figure 1–11 *You can see by the way this chameleon walks lightly across the hot road that temperature has an effect on almost all living things. Scientists measure temperature in degrees Celsius.*



1-2 SECTION REVIEW

1. List each step in the scientific method.
2. Define hypothesis. Compare a hypothesis and a theory.
3. What is the only difference between a control setup and an experimental setup?
4. Must the steps in the scientific method always be followed in the same order? Explain your answer.
5. If an experiment does not confirm the hypothesis it was designed to test, has that experiment "failed"?

PROBLEM SOLVING IN BIOLOGY

DIMENSIONAL ANALYSIS

Many times in science you will need to convert one unit of measurement to another. For example, you might be given a problem in kilometers but need the answer in centimeters. The process of converting one unit to another is called dimensional analysis.

Dimensional analysis involves determining three important facts: in what unit your measurement is given, in what unit it should be expressed, and what relationship between the units will allow you to make the conversion. The relationship between the units is called a conversion factor. A conversion factor expresses an exact relationship between the original unit and the desired unit. It is a fraction whose value is 1. For example,

$$\frac{60 \text{ minutes}}{1 \text{ hour}} \text{ or } \frac{1 \text{ liter}}{1000 \text{ milliliters}}$$

Although the numerator (top) of the fraction and the denominator (bottom) of the fraction are different, their actual values are the same. You see that 60 minutes equals 1 hour and 1 liter equals 1000 milliliters.

Any number can be multiplied by 1 without changing its value. Multiplying a measurement by a conversion factor, then, does not change the value of the measurement. This means that you can convert the given unit to the desired unit by multiplying by an appropriate conversion factor. You must, however, choose the correct form of the conversion factor. The unit to be converted must cancel out and the desired unit remain. Thus, the denominator of the conversion factor must contain the same unit as the one given to enable them to be canceled. Similarly, the numerator must contain the unit to be in the answer.

The following example shows how a typical dimensional analysis problem is solved.

Sample Problem Your friend runs 2500 meters while you run 3 kilometers. Using kilometers, which one of you has run a longer distance?

Step 1: Determine the given unit and the desired unit.

given: meters
desired: kilometers

Step 2: Find the relationship between the units and consider the possible conversion factors.

1000 meters = 1 kilometer
therefore:

$$\frac{1 \text{ kilometer}}{1000 \text{ meters}} = 1 \text{ or } \frac{1000 \text{ meters}}{1 \text{ kilometer}} = 1$$

Step 3: Choose the conversion factor whose denominator has the same units as your given value.

$$\frac{1 \text{ kilometer}}{1000 \text{ meters}} = 1$$

Step 4: Write the original value next to the conversion factor with a multiplication sign between them. Cancel like terms (shown in red).

$$2500 \cancel{\text{ meters}} \times \frac{1 \text{ kilometer}}{1000 \cancel{\text{ meters}}}$$

Step 5: Multiply the resulting equation.

$$2500 \times \frac{1 \text{ kilometer}}{1000} =$$

$$\frac{2500 \text{ kilometers}}{1000} = 2.5 \text{ kilometers}$$

Your friend has run 2.5 kilometers and you have run 3 kilometers. You have run the longer distance!

Practice Problems

Now try your hand at some dimensional analysis problems. You may choose to use a calculator or computer to do the arithmetic calculations.

1. In order to compare the results of several experiments, you need to have all your data in the same unit. Convert the following measurements to the same unit.
   16 kilograms 0.002 kilograms
   888 grams 155 milligrams
2. A recipe calls for 300 milliliters of water. You add 0.25 liters. Have you put in too much, too little, or the right amount?
3. Determine which of the following measurements is largest: 1800 centimeters, 2.1 meters, 0.0017 kilometers.
4. You are told that you need a jar with a volume of at least 150 cm^3. The label on the jar you find says 0.16 liters. Can you use it?
5. Calculate the number of seconds in 1 year. Then calculate the number of seconds in a decade.

1–3 Science: "Facts" and "Truth"

Section Objectives

- Relate the process of science and change.
- Identify successful study habits.

Scientific knowledge is a constantly changing body of observations. Many "scientific facts" of the past are now known to be false. For much of human history, for example, people "knew" that the Earth was flat, that the sun revolved around the Earth, and that rain fell through holes in heaven from a huge water tank in the sky. Those were the "facts" of an earlier time.

Now, of course, we "know" that the Earth is round (more or less), that the Earth and other planets revolve around the sun, and that rain falls from clouds made of water vapor. These are the scientific "facts" of today—the best explanations of the world around us that scientists have developed so far.

But new discoveries will be made. New theories will be born. Without a doubt, some of what you learn this year will have to be changed one day. Yet this does not mean that science has failed. On the contrary, it means that science continues to succeed in advancing our understanding of the world. Science is not a collection of eternal truths. Rather, it is a process, a way of looking at and understanding the world. And science will continue to change as long as humans wonder about the universe.

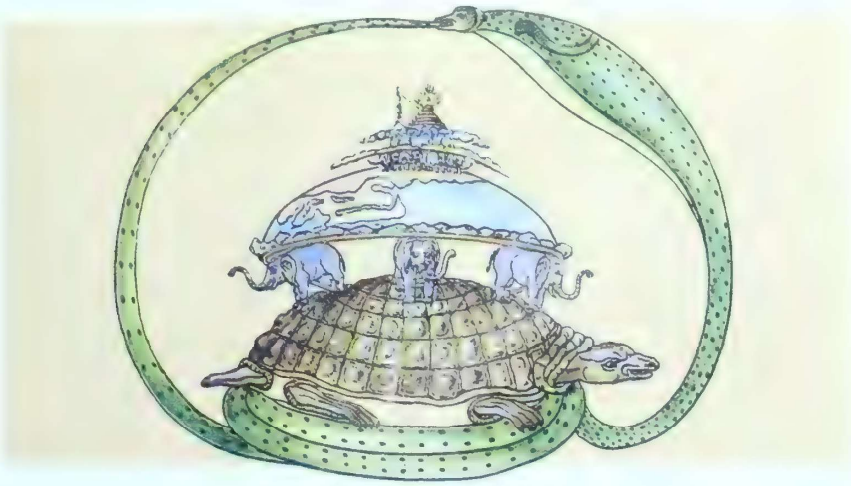
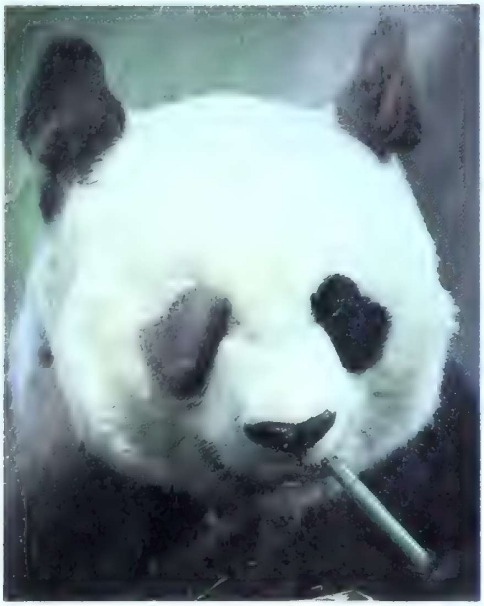
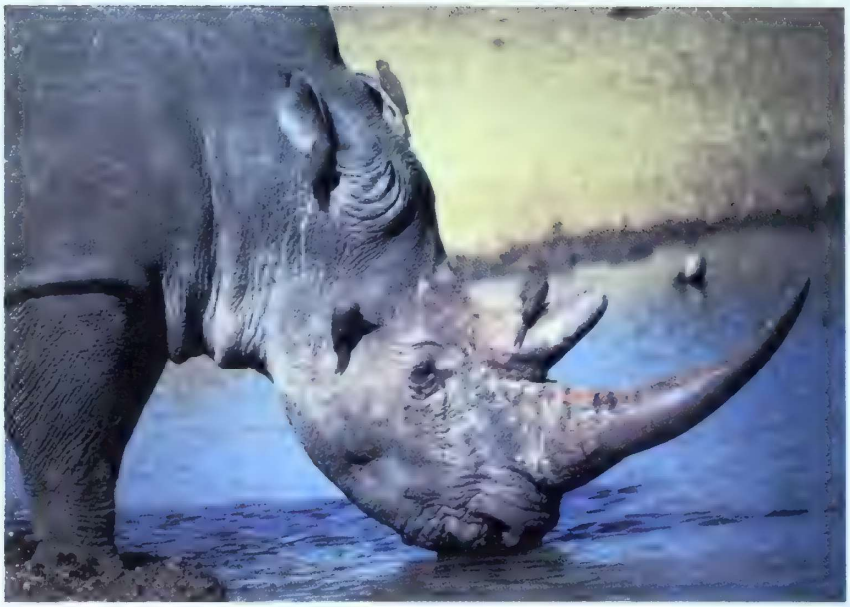


Figure 1–12 *As knowledge grows, facts can change. This print depicts a Hindu legend that tells that the Earth is supported by three elephants resting on the back of a giant tortoise.*





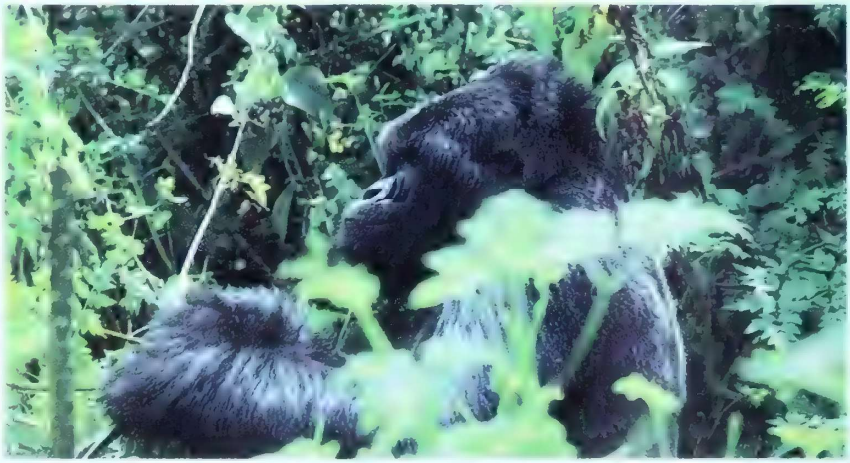


Figure 1–13 *The giant panda (top, left), the white rhinoceros (top, right), and the mountain gorilla (bottom) all look very different. So it might seem that the best way to study these animals is to memorize individual facts about each one. However, if you organize them as a group of mammals, then you will find it easier to learn about them. For all mammals share certain characteristics, no matter how different they may appear. These three particular mammals have another important thing in common —they are endangered species.*

How to Study Science

We, as scientists, sincerely hope that you will find your study of science to be both interesting and rewarding. For an understanding of science is essential to all of us in today's high-tech world. To make your learning easier and more enjoyable, we suggest you study science in a special way. First, do not try to memorize the contents of this book as a list of separate facts. Learning science this way will only make the process more difficult than it needs to be. Isolated facts will show little connection with each other in your mind. It will be as though you wrote each fact on a separate index card and then shuffled dozens of index cards together.

It makes much more sense to arrange facts you need to know in groups according to subject. As you read this book, work at understanding, rather than just memorizing, the topics we talk about. When you study the parts of the cell, for example, don't just memorize their names. Think about what each

part does. Remember how each part works with other parts within the cell as a whole. Learning this way is like organizing the index cards of facts into groups that have meaning for you. Then when you need a particular fact, you can look for it under its proper subject heading. That will make it much easier to remember what you need.

Second, remember that science is a process. In addition to learning the scientific facts of today, try to appreciate the process of discovery. Try to see the thinking behind the experiments we describe. Try to understand the kinds of questions scientists ask as they struggle to make sense out of the world. Follow along as we describe the discovery of genes and the development of evolutionary theory. If you can learn to think the way scientists think, you will get a lot more than facts from this course. You will develop the ability to understand the process of science and to be at home in a world that will change constantly throughout your life.

Science and Human Values

An important goal in science is to be objective. But scientists are no different from the rest of us when it comes to emotions or personal opinions. Scientists, after all, are people too—people with likes, dislikes, and occasional biases.

In today's world, scientists have important things to say about questions that are raised regarding health, society, and the environment. Shall we build a nuclear power plant? Dam a river? Develop forest lands into homesteads? Should chemical wastes be buried, burned, or dumped at sea? Are there ways to use chemical wastes for our benefit? Should certain experiments involving humans be forbidden? All of these questions rely on science for at least part of their answers.

But scientific data can be misinterpreted or misapplied by scientists who want to prove a particular point. And decisions made by scientists with personal prejudices may or may not be in the public interest. What this means to you is that understanding science is even more important today than ever before. If enough people understand the nature of science, the dangers posed by misinterpreted or misleading information will be reduced.

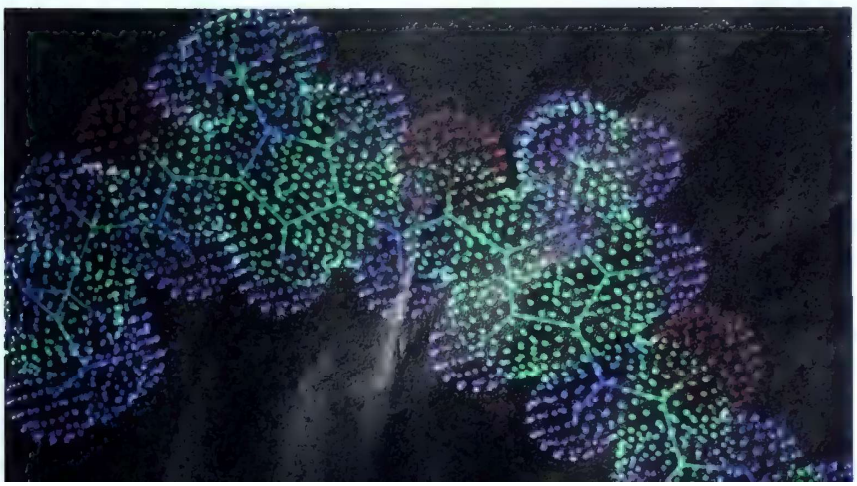




Figure 1–14 *No doubt about it — we live in a high-tech world. Computers are now used to show the chemical structure of molecules such as this portion of a human protein (left). Advances in physics, such as superconductors (right), may revolutionize the ways in which we travel and transmit electricity. As a citizen, you will have to make important decisions about the role of science in society. In order to do this, you must be able to read, understand, and evaluate scientific information.*

Luckily, men and women of science are taking action. Biologists, chemists, and physicists are speaking out about safety problems involved with nuclear power. Biologists and chemists are warning of the dangers posed by too many chemicals in food and water. And biologists are describing the serious threat to our environment posed by acid rain. We will touch on these and other matters in this book, and we hope that you will keep track of such issues, both in your local community and in the world at large.

1-3 SECTION REVIEW

1. Science will not sit still and allow itself to be memorized. You cannot "learn" biology, stick it away in some mental closet, and pull it out years later. Why is this the case?
2. What is the best way to study science? Why?
3. Why is it important that everyone understand the process of science and the nature of scientific facts?

Section Objective

- Identify and apply proper rules when working in the laboratory.

1-4 Safety in the Laboratory

Biology does not happen in books or in scientists' minds. Biology is most alive and exciting where the experiments that test hypotheses actually take place—in the laboratory and in the field. That is why your course in biology will probably include several laboratory exercises. Only in the laboratory can you perform experiments to learn about the process of science at first hand. Only in the laboratory can you see, touch, and manipulate living systems to understand them more thoroughly.

In the laboratory—as in any place where there are chemicals, flames or heating elements, hot liquids, and electricity—it is important to follow certain basic safety precautions. These precautions are not directed only at you as students. Scientists with many years' experience know that laboratory safety is of prime importance. The experiments you will carry out this year have been tried and tested many times. When properly performed, they are both interesting and educational. However, if laboratory materials are handled carelessly, accidents can happen.

Figure 1-15 *What important safety precautions are these students taking while working in the laboratory?*



The single most important rule for you in the laboratory is simple: Always follow your teacher's instructions and the textbook directions exactly. If you are in doubt about what to do, always ask first. Use Figure 1-16 to familiarize yourself with safety symbols and the rules of laboratory safety. Read the rules and make certain that you understand them. If you are not sure that you understand a rule completely, ask your teacher to explain it.

LABORATORY SAFETY: RULES AND SYMBOLS

Glassware Safety

1. Whenever you see this symbol, you will know that you will be working with glassware that can easily be broken. Take particular care to handle such glassware safely. And never use broken glassware.
2. Never heat glassware that is not thoroughly dry. Never pick up any glassware unless you are sure it is not hot. If it is hot, use heat-resistant gloves.
3. Always clean glassware thoroughly before putting it away.

Fire Safety

1. Whenever you see this symbol, you will know that you will be working with fire. Never use any source of fire without wearing safety goggles.
2. Never heat anything—particularly chemicals—unless instructed to do so.
3. Never heat anything in a closed container.
4. Never reach across a flame.
5. Always use a clamp, tongs, or heat-resistant gloves to handle hot objects.
6. Always maintain a clean work area, particularly when using a flame.

Heat Safety

Whenever you see this symbol, you will know that you should put on heat-resistant gloves to avoid burning your hands.

Chemical Safety

1. Whenever you see this symbol, you will know that you will be working with chemicals that could be hazardous.
2. Never smell any chemical directly from its container. Always use your hand to waft some of the odors from the top of the container toward your nose—and only when instructed to do so.
3. Never mix chemicals unless instructed to do so.
4. Never touch or taste any chemical unless instructed to do so.
5. Keep all lids closed when chemicals are not in use. Dispose of all chemicals as instructed by your teacher.
6. Immediately rinse with water any chemicals, particularly acids, off your skin and clothes. Then notify your teacher.

Eye and Face Safety

1. Whenever you see this symbol, you will know that you will be performing an experiment in which you must take precautions to protect your eyes and face by wearing safety goggles.
2. Always point a test tube or bottle that is being heated away from you and others. Chemicals can splash or boil out of the heated test tube.

Sharp Instrument Safety

1. Whenever you see this symbol, you will know that you will be working with a sharp instrument.
2. Always use single-edged razors; double-edged razors are too dangerous.
3. Handle any sharp instrument with extreme care. Never cut any material toward you; always cut away from you.
4. Notify your teacher immediately if you are cut in the lab.

Electrical Safety

1. Whenever you see this symbol, you will know that you will be using electricity in the laboratory.
2. Never use long extension cords to plug in an electrical device. Do not plug too many different appliances into one socket or you may overload the socket and cause a fire.
3. Never touch an electrical appliance or outlet with wet hands.

Animal Safety

1. Whenever you see this symbol, you will know that you will be working with live animals.
2. Do not cause pain, discomfort, or injury to any animal.
3. Follow your teacher's directions when handling animals. Wash your hands thoroughly after handling animals or their cages.

Figure 1–16 *You will see these safety symbols in the Laboratory Investigations in this textbook and in your Laboratory Manual. Make sure you understand the meaning of each symbol. If you are not sure what a symbol means, ask your teacher.*

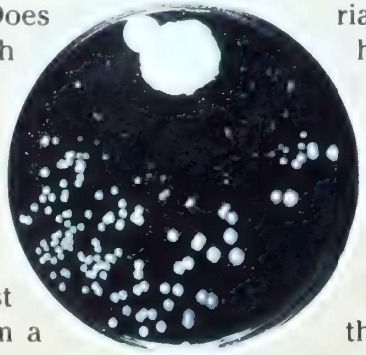
1–4 SECTION REVIEW

1. What is the most important general rule to follow when working in the laboratory?
2. Where is the nearest fire extinguisher located in your laboratory or classroom?
3. What sort of instruments might you be more likely to find in a biology laboratory than in a chemistry laboratory?

SCIENCE, TECHNOLOGY, AND SOCIETY **BREAKTHROUGH**

The Odd Couple: A Messy Lab and a Keen Mind

Some of us professional scientists, despite our efforts, aren't very neat workers in the lab. Oh, sure, we can keep things sterile when they need to be. But as a rule, some of us are a little messy and disorganized. Does that fit in science? Does it match our description of the scientific method? It may not match, but the messy scientist is in good company. One messy scientist was a man named Alexander Fleming.



History records at least two of Fleming's sloppy mistakes. The first was in 1922. He was suffering from a bad cold and accidentally allowed a few drops from his runny nose to drip on a plate of bacteria he was growing. Instead of discarding the dish, Fleming watched it for days. What happened? Lo and behold—the bacteria died! Fleming had discovered lysozyme, a chemical in tears and mucus that helps protect the body against bacteria.

More important work followed. Six years later, Fleming was growing more bacteria. He saw that some of his plates had been contaminated with a greenish mold (*Penicillium*) that grows on bread. Once again Fleming's sloppiness was to blame. But his careful eye and keen mind made something of the event. He saw a clear spot on the culture dish, indicating that the bacteria near the mold had died. The mold was making something that was killing the bacteria. That something turned out to be a chemical that has saved millions of lives: penicillin. Science works that way. It is a very human enterprise—one that even has room for us messy scientists!

Section Objective

- Compare planet Earth to a spaceship traveling through the universe.

1–5 The Spaceship Called Earth

Seen by astronauts from space, Earth is incredibly beautiful. It shines blue, white, and purple against the black, airless void. Since the beginning of human history, poets have written about the beauty of Earth. Artists have created paintings of Earth's magnificent wilderness lands and wild animals. Today, scientists from several fields are warning us that we must learn to protect our planet and preserve its living treasures. Our species has rapidly developed the ability to change the Earth much for the better and much for the worse. We have saved many species from extinction. At the same time, we have destroyed hundreds of other species. We have made gardens bloom in deserts and can now feed more people than ever before. But we have also turned fertile land into dust bowls. We have tremendously increased human life spans and can treat or cure many diseases that were once fatal. Yet we have also manufactured chemicals that once seemed useful but now threaten our health and the health of other species.

Earlier in human history, the Earth seemed to be without end. There were always new wildernesses to settle, new resources to use, and plenty of places to dump our garbage. Now we know that there is limited land—and limited amounts of clean air, water, and other resources. There are also a limited number of places we can use as trash heaps. **The Earth is no longer a planet without end. It is more like a giant spaceship with a living cargo, carrying limited amounts of vital supplies.**

As you read this book, you will learn about the basis of life and about the process by which life has evolved. You will take a tour through the kingdoms of the different kinds of organisms with whom we share our planet. You will learn just how closely all forms of life on Earth are connected. We hope you will also learn how important it is to preserve that life. More than ever before in history, we must work to protect our environment against destruction. Properly applied, science can provide us with the knowledge and tools we need to meet this challenge. We think you will agree that the joys of a ride on spaceship Earth are more than worth the responsibilities we have as its most powerful passengers.

1–5 SECTION REVIEW

1. How does our modern view of Earth's resources differ from older impressions?
2. What are some of the great successes of human endeavors on Earth? What are some of the failures?



Figure 1–17 *Humans have changed the Earth both for the better and for the worse. Vaccines help to prevent many diseases that were once fatal. Modern farming methods can now feed more people than ever before. At the same time, however, we have seen numerous species of living things destroyed by the actions of humans. And we have allowed toxic wastes to seep into our soil and waterways.*

LABORATORY INVESTIGATION

INTERPRETING A CONTROLLED EXPERIMENT

PROBLEM

What effect does the amount of water given to seeds have on the rate of seed germination?

MATERIALS *(per group)*

200 mustard seeds
3 petri dishes with covers
2 50-mL beakers
graduated cylinder
glass-marking pencil

PROCEDURE



Part A

1. In this investigation you will determine whether the amount of water given to mustard seeds has an effect on the number of seeds that germinate, or sprout. Before you begin, propose a hypothesis predicting the effect that varying amounts of water might have on mustard seed germination. The steps that follow will help you test your hypothesis.
2. Place 50 mustard seeds in each of two petri dishes.
3. Using the graduated cylinder, pour 5 mL of water into one petri dish. Then pour 30 mL of water into the other petri dish. Cover each petri dish. Use the glass-marking pencil to indicate the volume of water in each.
4. Set both petri dishes aside for 48 hours. After 48 hours, count the number of seeds in each petri dish that have begun to germinate. Record your observations in a data table similar to the one shown here.

Part B

1. Place 50 mustard seeds in each of the two beakers.
2. Using the graduated cylinder, pour 5 mL of water into one beaker and 30 mL of water into the other. Cover each beaker with the top or bottom of the remaining petri dish. Then, using the glass-marking pencil, indicate on the cover the volume of water in each beaker.
3. Set the beakers aside for 48 hours. After 48 hours, count the number of seeds in each beaker that have begun to germinate and record your results in your data table.

OBSERVATIONS

Type of Container	Volume of Water	
	5 mL	30 mL
Petri dish		
Beaker		

1. Did the mustard seeds float in any of the containers? If so, were these seeds more likely to germinate?
2. In which container did the germinated seeds have the longest roots?

ANALYSIS AND CONCLUSIONS

1. How did the number of germinated seeds in the petri dishes compare to the number of germinated seeds in the beakers?
2. Did the amount of water in the petri dishes appear to affect the number of germinated seeds? Did these results confirm your hypothesis?
3. Did the amount of water in the beakers appear to affect the number of germinated seeds? Did these results confirm your original hypothesis?
4. Sometimes the results of different parts of an experiment provide different interpretations. When this occurs, scientists often look to see if a hidden variable, which might affect the overall results of an investigation, was introduced. What hidden variable might account for the results you observed in the petri dishes and in the beakers? (*Hint:* Other than water, what substance may have played a role in your experiment?)

STUDENT STUDY GUIDE

SUMMARIZING THE CONCEPTS

The key concepts in each section of this chapter are listed below to help you review the chapter content. Make sure you understand each concept and its relationship to other concepts and to the theme of this chapter.

1–1 What Is Science?

- Science is a process that uses observations and tests to identify the causes of events in nature.

1–2 The Scientific Method

- The main steps in the scientific method are observing and stating a problem, forming a hypothesis, testing the hypothesis through observation or experimentation, recording and analyzing data, forming a conclusion, and replicating the work.
- A hypothesis is a possible explanation about a particular event in nature.
- In order to ensure that the results of an experiment were due to the variable being tested, scientists must run both an experimental setup and a control setup.
- When a hypothesis has been tested and confirmed many times, it may then be considered a theory that can make dependable predictions about nature.
- The metric system is the system of measurement used by scientists all over the world.
- Although mass and weight are considered interchangeable on the surface of the Earth, mass is actually a measure of the amount of matter in an object and weight is a measure of the pull of gravity on that object.

1–3 Science: "Facts" and "Truth"

- Successful science study habits involve relating facts to each other and to the underlying concepts being discussed rather than simply memorizing a list of facts.

1–4 Safety in the Laboratory

- Always follow all written instructions or instructions from your teacher whenever working in the science laboratory.

1–5 The Spaceship Called Earth

- Planet Earth can be compared to a giant spaceship carrying a living cargo and limited amounts of food, water, and other resources.

REVIEWING KEY TERMS

Vocabulary terms are important to your understanding of biology. The key terms listed below are those you should be especially familiar with. Review these terms and their meaning. Then use each term in a complete sentence. If you are not sure of a term's meaning, return to the appropriate section and review its definition.

1–1 What Is Science?
science

1–2 The Scientific Method
scientific method
hypothesis
variable
control setup
experimental setup
data
theory
metric system
meter
liter
cubic centimeter
mass
weight
kilogram
Celsius scale

CHAPTER REVIEW

CONTENT REVIEW

Multiple Choice

Choose the letter of the answer that best completes each statement.

1. A proposed solution or explanation of a scientific event in nature is called a
   a. conclusion. c. control setup.
   b. hypothesis. d. theory.
2. The factor being tested in an experiment is the
   a. data. c. variable.
   b. hypothesis. d. theory.
3. The metric system is based or scaled on powers of
   a. 10. c. 1000.
   b. 100. d. none of these.
4. The basic unit of length in the metric system is the
   a. meter. c. millimeter.
   b. kilometer. d. centimeter.
5. The basic unit of mass in the metric system is the
   a. gram. c. liter.
   b. kilogram. d. pound.
6. A cubic centimeter is equivalent to a
   a. liter. c. milligram.
   b. gram. d. milliliter.
7. Which of the following relationships between an object on Earth and that same object on the moon is true?
   a. mass changes; weight remains the same
   b. neither mass nor weight changes
   c. both mass and weight change
   d. weight changes; mass remains the same
8. If you see the symbol of a flask in a laboratory experiment, you are being cautioned to
   a. put on goggles.
   b. take extra care with glassware.
   c. make sure your measurements are very precise.
   d. use heat-resistant gloves.

True or False

Determine whether each statement is true or false. If it is true, write "true." If it is false, change the underlined word or words to make the statement true.

1. Recorded observations are called data.
2. The control experiment is that part of the experiment without the variable.
3. A kilometer contains 1000 centimeters.
4. A milliliter contains 1000 cubic centimeters.
5. The prefix *centi-* means one hundred.
6. In science, facts never change.
7. The goal of science is to understand the world around us.
8. The kilogram is the unit of mass you would use to measure objects smaller than a gram.

Word Relationships

Replace the underlined definition with the correct vocabulary word.

1. The ability to reproduce results is an important part of any experiment.
2. After observing an event in nature, a scientist may develop a possible explanation or a preliminary conclusion regarding the cause of that event.
3. The liter is a measure of the amount of space an object occupies.
4. Scientists often measure length in hundredths of a meter.
5. The amount of matter in an object can be measured in milligrams.

CONCEPT MASTERY

Use your understanding of the concepts developed in the chapter to answer each of the following in a brief paragraph.

1. Why is it important to have only one variable in an experiment?
2. Scientists throughout the world use a standard system of measurement. Why is a standard measurement system necessary?
3. Why must science textbooks be revised every few years?
4. Compare planet Earth to a giant spaceship.
5. Describe the approach that separates the process of science from other fields of study.
6. Which metric unit would you use to measure each of the following:
   a. volume of a glass of milk
   b. length of your textbook
   c. mass of a mouse
   d. temperature of the Gulf of Mexico
   e. mass of a killer whale
   f. volume of a marble

CRITICAL AND CREATIVE THINKING

Discuss each of the following in a brief paragraph.

1. **Designing an experiment** How would you use the scientific method to find the best place in your class to grow African violets?
2. **Making predictions** Develop a time line in which you predict some of the important advances that may occur in science during the next century.
3. **Interpreting diagrams** Examine the illustration of a control setup and an experimental setup. What is the variable in this experiment? Why?



4. **Recognizing fact and opinion** Suppose your friends believe that astrology is a science. How would you convince them that they are wrong?
5. **Relating concepts** The French biologist Louis Pasteur once said, "Chance favors only the mind that is prepared." Explain this statement by relating it to the process of science.
6. **Using the writing process** You have been elected to the Senate. The most important issue that has to be resolved is whether the United States will convert to the metric system. Write a 3-minute speech detailing your reasons for adopting or rejecting the metric system.
7. **Using the writing process** The year is 2050. Write a help-wanted ad that will encourage high school graduates to volunteer for a 2-year mission to planet Mars. The main task of the graduates will be as technicians helping out in various scientific experiments. All graduates will be trained before the mission begins.